The Alaska Integrated Ecosystem Model: An Interdisciplinary Tool to Assess the Responses of Natural Resources in Alaska to Climate Change

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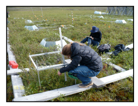
Abstract: B33E-0562

Introduction

Alaska land managers are increasingly asked to consider the effects of climate change as an element in the planning process, and in environmental impact analyses. Yet, there are few tools available with which to visualize future landscapes. The Alaska Integrated Ecosystem Modeling (IEM) Project is a multi-institutional and multi-disciplinary enterprise designed to meet Alaska land managers' need to understand the nature and rate of landscape change.

We know that the physical and biotic components of the arctic and boreal ecosystems — permafrost, hydrology, disturbance (e.g., fire) and vegetation — are tightly linked and sensitive to climate change. The goal of the Alaska IEM is to develop a dynamically linked model that will act as a support tool for decision makers. The Alaska IEM incorporates climate-driven changes to vegetation, disturbance, hydrology, and permafrost, and their interactions and feedbacks.



Pilot Phase

The project's pilot phase (2010-2011) produced a conceptual framework for linking three models of ecosystem processes in Alaska – ALFRESCO, TEM, GIPL – and the primary processes of succession, fire, hydrology, and permafrost that they simulate (Fig. 1).

A proof-of-concept model run was completed, in which the ALFRESCO model provided information about fire occurrence and severity to TEM, and TEM provided information on surface vegetation and organic layer properties to GIPL, which was incorporated into a projection of permafrost and soil conditions. The Alaska Yukon River Basin was used as the test study area

Preliminary results of the pilot study suggest that the distribution of permafrost may decline from over two-thirds of the Alaska Yukon River Basin to 20%-30% (Fig. 2). In addition, fire activity in the study area is projected to remain high until mid-century, after which it will decline because of a shift toward less flammable deciduous forest.

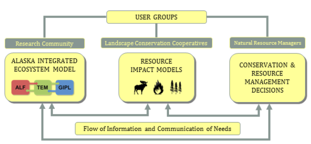


Figure 1. The Alaska IEM will directly serve the research community, provide required data streams for resource impact models and serve as a tool for natural resource managers.

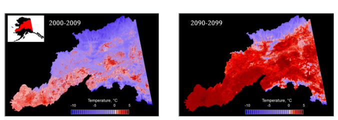


Figure 2. Mean annual ground temperatures at 1 m depth in the Alaska Yukon River Basin for an asynchronous coupled run simulated by the permafrost regime model GIPL. Simulated ground temperatures are driven by historical (2000-2009) and projected climate change scenarios (2090-2099). Blues depict temperatures <0°C and reds depict >0°C, indicating areas most likely to experience permafrost degradation over the next century.

The Big Picture

The physical and biotic components of arctic and boreal ecosystems – ***permafrost, hydrology, disturbance and vegetation*** – are linked and sensitive to climate change. Managers need tools to visualize future landscapes that may result from the interaction of ecosystem components and physical processes. The Alaska IEM will provide a support tool for forecasting ecosystem change and informing natural resource management.

Phase II

In the next phase of this multi-year project (2011-2016), our objectives are to synchronously couple the models, develop datasets for Alaska and adjacent areas of Canada (Fig. 3), and phase in additional capabilities necessary to address the effects of climate change.

Working with our Landscape Conservation Cooperative (LCC) partners, we identified three priority issues that need to be incorporated into the synchronous model: (1) tundra fire and treeline dynamics, (2) landscape-level thermokarst dynamics and (3) wetland dynamics.

Ultimately, this support tool will provide an integrated framework for natural resource managers and decision makers and produce specific scenarios of changes in landscape structure and function that could be used by resource-specific impact models (Fig. 4).

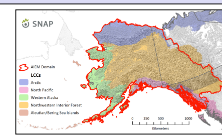


Figure 3. Geographic domain for the Alaska IEM and location of Landscape Conservation Cooperatives (LCCs).

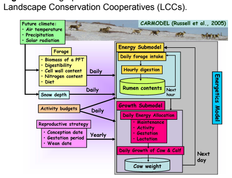


Figure 4. An example of a resource-specific impact model: The Caribou Energetics Model (CARMODEL).

Also see abstracts B33E-0555 and B11C-0453

Tundra Fire and Treeline Dynamics

The incorporation of tundra fire and vegetation succession dynamics into the Alaska IEM will allow us to better forecast changes in landscape structure and function in northern and northwest Alaska.

ALFRESCO (Fig. 4) will provide TEM with information on burn severity and tree establishment in tundra regions and TEM will model successional dynamics after fire. We are currently developing and evaluating the exchange of these data between the two models. In the second year of the project, we will fully incorporate these dynamics into the Alaska IEM and conduct a proof of concept study.

In 2013-2016, we will assess climate change responses over the entire Western Arctic in a version of the Alaska IEM that includes tundra fire and treeline dynamics. In addition, we will develop resource impact models specific to tundra fire and treeline dynamics. These models will be defined by engaging Arctic and Western Alaska LCC stakeholders about priorities for the focus of resource impact studies

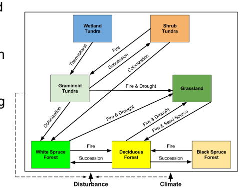


Figure 4. Conceptual diagram of the ALFRESCO model. The model simulates the response of vegetation to transient climate change. The model assumptions reflect our hypothesis that fire regime and climate are the primary drivers of landscape-level changes in the distribution of vegetation in arctic and boreal ecosystems.

Also see abstracts B23F-0517 and B23F-0524

Thermokarst Dynamics

The Alaska Thermokarst Model (ATM) is a state-and-transition model, simulating thermokarst initiation and expansion in boreal and arctic ecosystems in Alaska. The model is designed to be integrated into the Alaska IEM (Fig. 5).

Thermokarst initiation and expansion are controlled by probabilistic rules that respond to climate, disturbance and site characteristics. These factors are considered in a hierarchical fashion to simulate thermokarst dynamics: predisposing factors, initiation factors, and expansion factors.

Predisposing factors include topography, ground ice content and soil texture. Initiation factors include climate and fire. Expansion factors include climate and environmental conditions such as hydrology, erosion, soil texture and ice content.

The model tracks thermokarst disturbance and associated vegetation transitions within a 1x1 km resolution grid cell.

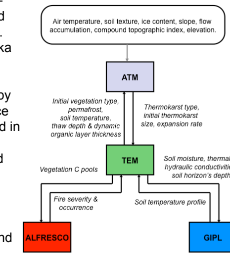


Figure 5. The Alaska Thermokarst Model (ATM) is to be integrated into the Alaska IEM by communicating information on thermokarst type, initiation and expansion rate through the Terrestrial Ecosystem Model (TEM).

Also see abstracts B21D-0388 and B21D-0391

Wetland Dynamics

To eventually incorporate wetland dynamics into the Alaska IEM framework, we are initially conducting field studies in the boreal forest of Interior Alaska (Fig. 6).

The aim for this work is to better understand carbon and vegetation dynamics for boreal fens and collapse-scar bogs. The knowledge gained will then be used to model how transitions from thermokarst disturbance (e.g., boreal forest permafrost plateau to boreal collapse-scar bog) influence ecosystem structure and function.

Preliminary data indicate that death of trees and anaerobiosis associated with thermokarst disturbance results in reduced CO_2 sink strength and sigificant CH_4 fluxes in a newly formed collapse-scar bog.

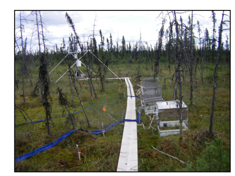
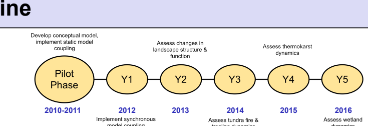


Figure 6. The collapse-scar bog field site in the boreal forest of Interior Alaska showing the eddy covariance tower and autochambers.

Also see abstracts B14D-03 and C23E-03

Timeline



The Alaska Climate Science Center provides scientific information, tools and techniques that managers and parties interested in land, water, wildlife and cultural resources can use to anticipate, monitor and adapt to climate change.

To learn more about the Alaska IEM: Visit http://www.snap.uaf.edu/projects.php or contact Dr. Amy Breen (UAF) at albreen@alaska.edu, or Dr. Stephen Gray (DoI Alaska Climate Science Center) at sgray@usgs.gov.